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ORIGINAL RESEARCH PAPER

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A STUDY OF CORROSION CONTROL IN PIPELINES

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ABSTRACT

Pipeline corrosion is the deterioration of pipe material and the related system due to its interaction with the working environment. It affects pipeline and accessories made of both metals and non-metals. Pipeline corrosion—and the related catastrophic failures that it can cause—cost billions of dollars to the economy. The total annual cost of corrosion in 2016, including direct and indirect costs, was estimated at over USD $1.1 trillion in the United States. In other words, corrosion is a big problem. It predominantly affects pipelines made of metals such as copper, aluminum, cast iron, carbon steel, stainless steel and alloy steel pipes used for buried, underground, submerged or other pipelines. That makes designing and selecting the best available systems and materials for pipelines and their corrosion protection systems an extremely important issue for the oil and gas industry. In this research paper we will investigate and take a look at the key types of corrosion that affect pipelines, and some of the methods that are used to protect this infrastructure.

INTRODUCTION

Oil and gas field pipelines typically fall into two categories: one is used for transportation of untreated well head fluid, and the other is used for transportation of treated fluid. Pipelines are used for transportation of single-phase or multiphase fluids. In oil and gas exploration and production operations, these pipelines are used to connect crude oil and natural gas wells to process facilities, transport processed fluids from offshore platforms to shore, and then on to processing, transport of treated water for injection applications, or for custody transfer. Failure of pipelines can hamper the operations of an entire oil and gas asset because nothing can be transported. Even if offshore and onshore facilities are well-operated and managed, failure of pipelines may bring all operations to a stop because of connectivity failure.

These pipelines are designed based on initial operational requirements. The material of construction is selected per those requirements. Often, the designed pipeline cannot withstand conditions other than those of its originally designed purpose. For example, if a pipeline is designed for treated natural gas, it may have corrosion problems if switched to carry untreated natural gas. Laying subsea pipelines takes considerably more time and money than laying comparable onshore pipelines because of underwater work and seasonal sea conditions. Accordingly, the operator engaged in exploration and production of oil and natural gas lays subsea pipelines as per the requirement only, and there may not be any standby pipeline in case of failure. This too is the case of onshore pipelines and process equipment. So clearly, the integrity of a pipeline directly affects crude oil and natural gas production. Figure 1 shows the pertinent categories of pipeline services and related actions.

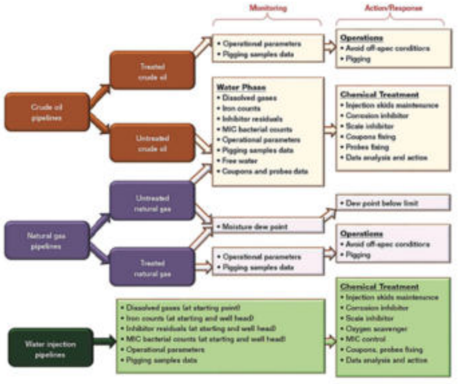

Figure 1 Pertinent categories of pipeline services and related actions

Ensuring long-term, cost-effective system integrity requires an integrated approach based on the use of inspection, monitoring, mitigation, forensic evaluation, and prediction. Inspections and monitoring using sensors can provide valuable information regarding past and present exposure conditions but, in general, they do not directly predict remaining life. Carefully validated computer models, on the other hand, can predict remaining life; however, their accuracy is highly dependent on the quality of the computer model and associated inputs. Mitigation (corrosion prevention) methods and forensic evaluations play a key role in materials selection, assessment and design.

THE CORROSION PROCESS

Corrosion of most pipelines occurs due to an electrochemical reaction in the presence of an electrolyte. The electrochemical nature of the process also facilitates the detection and mitigation of this deterioration, which is accomplished by monitoring the voltages and the currents associated with the corrosion rate. The rate of corrosion of a piping system is generally related to both external and internal factors. External factors include a working environment of pipes, soil chemistry and moisture for buried pipes or water chemistry in the case of submerged pipes.

Internal factors that contribute to corrosion may include:

- The oxygen content or reactivity of liquids and gases carried
- The use of dissimilar metals within the piping system
- The temperature, flow rate and pressure of the fluids and gases

TYPES OF PIPELINE CORROSION

There are several different types of corrosion. Here we will look at how they occur.

1. Uniform Pipe Corrosion

As the name indicates, uniform pipe corrosion causes uniform loss of the material along the surface of the pipe, resulting in a continuous thinning, or wall loss, of its solid structure. The rate of reaction is measured by the depth of penetration of the surface in millimeters per year. By selecting a suitable piping material and a combination of corrosion protection methods such as cathodic protection as well as surface coatings, it is possible to prevent this type of deterioration.

2. Pitting Corrosion

Pitting corrosion is the severe, localized deterioration of a limited surface area, leading to cavity formation, or pits, on a pipe's surface. In some cases, these pits may puncture the pipe.

The reasons for pitting corrosion include:

- Pipe material defects or surface defects
- Mechanical damage to the protective passive film
- Penetration by an aggressive chemical species, such as chlorides

This type of corrosion is frequently found in passive metal alloys and metals such as aluminum or even stainless steel. Pits normally vary in shape and depth. Improper material selection for piping can be one of the causes. This corrosion can be prevented by: Selecting a pipe material for the specific service environment, such as the temperature and chemical concentration of a reactant (resistant to pitting), Devising cathodic or anodic protection.

3. Selective Leaching

Selective leaching, or graphitic corrosion, occurs when a noble metal and a more reactive element form an alloy. This may result in the loss of the reactive element from the pipeline's surface, causing loss of strength and premature failure. A typical example of this is the removal of nickel, cobalt or zinc from copper alloys. This can result in color changes or changes in density in the affected material. The addition of aluminum or tin can, in some cases, provide protection from leaching.

4. Galvanic Corrosion

Galvanic corrosion occurs when dissimilar alloys or metals of different corrosion potentials are connected electrically. In this case, only the metal working as an anode with respect to the other will deteriorate. This reaction can be prevented by using a combination of metals that are closer in the galvanic series, and by placing insulation between the two. Coating of the cathodic surface will also help.

5. Crevice Corrosion

Crevice corrosion is caused by an accelerated reaction at joints and other crevices of a pipeline due to differential oxygen availability. The surfaces starved of oxygen become the anode in an electrochemical reaction. Replacing riveted joints with welded joints can help overcome such problems.

6. Intergranular Deterioration

Intergranular deterioration refers to the selective deterioration at a surface's grain boundaries (due to high temperature) when the grain boundary reaches high activity, which is prone to corrosion. Heat treatment and welding heat can cause this transformation, leading to corrosion. This problem can be prevented by selecting extra-low carbon stainless steel materials.

7. Cavitation and Erosive Corrosion

Cavitation damage occurs in a pipeline when the fluid's working pressure drops below its vapor pressure, leading to the formation of vapor pockets and vapor bubbles that collapse at the internal surface of the pipeline. This can also lead to erosive corrosion. Parts of pipelines such as pump suctions, discharge pipes, elbows, tees or expansions or fitments at heat exchangers, even valve seats may be extremely prone to this damage under certain operational conditions. Cavitation can be prevented at the design stage by reducing fluid pressure gradients and excessive pressure drops in the range of the vapor pressure of the liquid, as well as ensuring zero air ingress. Coatings can also reduce the rate of material loss.

Erosion corrosion is due to the relative movement of fluid and the inner surface of the pipe. Fluid turbulence can result in a rapid rise in erosion rates. Poorly finished internal pipe surfaces or pits that may form can disturb smooth fluid flow, leading to localized fluid turbulence. This can result in a high erosion rate. A combination of cavitation, erosion and corrosion, at a high temperature or high pressure, can lead to very severe pitting corrosion. The addition of chromium or molybdenum to steel can improve the corrosion protection in this case.

8. Cathodic Protection (CP)

Cathodic protection (CP) is an electrical method of reducing the corrosion rate of a pipe's metal surface by converting it into the cathode of an electrochemical cell. This is achieved by moving the potential of the pipe metal into the negative direction by impressing the necessary voltage through an external power source (in the case of an impressed current CP), or by providing a sacrificial anode in the system (in a galvanic CP).

In the case of an impressed current protection system, a calibrated current is superimposed on the piping structure by means of a dedicated power supply consisting of a rectifier-transformer connected to a local utility power source. This is connected to an anode buried in the ground. In the case of a galvanic CP (sacrificial anode) system, the galvanic hierarchy between a sacrificial anode metal, such as zinc, and the pipe metal, is used to supply the required protective current.

Sacrificial anodes are made of different alloys of aluminum, zinc or magnesium. For very large pipelines, sacrificial anodes cannot deliver enough protective current to ensure complete pipe protection. An impressed current cathodic protection system is selected under such conditions.

CONCLUSIONS

Studying the mode of corrosion damage of a particular pipeline aids in the determination of the root cause of corrosion, and a suitable solution. Corrosion can be minimized by selecting suitable systems and materials at the design stage. Cathodic protection systems facilitate the continuous monitoring of pipelines. While planning new pipelines, the advanced methods of monitoring and protection should be incorporated.

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